

The refraction limitations of accuracy in two-color SLR

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The effects of refraction on electromagnetic wave propagation in inhomogeneous Earth's atmosphere may be responsible for systematic error (biases) in result of two-color SLR measurements. Among these effects are both ray path refraction lengthening and refraction space struggling of trajectories of optical signals with various optical carrier wavelengths. The contribution of these effects to resulting error (uncertainty) of measurements depends on specific values of wavelengths used, constructional features and operational mode of two-color SLR station, zenith angle, current atmospheric conditions, distance up to satellite.

In this paper the physical and mathematical model for the evaluation of the effects mentioned above is presented. This model has been extended to the rangefinder with laser beam containing two components with various optical carrier wavelengths which is directed up to satellite as unified one. The calculations for various conditions of measurements and various sets of wavelengths (in particular for two-color rangefinders with $\lambda_1=423,5$ nm, $\lambda_2=847$ nm and $\lambda_1=532$ nm, $\lambda_2=355$ nm too) were performed. The formulae for calculations have been represented as [Prokopov and Remayev, 2000]

$$\delta D = L - \int_0^D d\sigma,$$

$$\delta_{str} = \frac{\alpha_2}{\alpha_1 - \alpha_2} \left[\delta D_1 - \delta D_2 + \Delta S_1 - \frac{\alpha_1}{\alpha_2} \Delta S_2 + (\Delta S_2 - \Delta S_{dry,2}) \left(\frac{\alpha_1}{\alpha_2} - \frac{\beta_1}{\beta_2} \right) \right],$$

$$\Delta S = \int_0^D (n - 1) d\sigma,$$

$$n = 1 + \alpha(\lambda) \cdot P(p, T) + \beta(\lambda) \cdot E(e, T),$$

where

n - refraction index of air;

ΔS - group delay (ΔS_{dry} - group delay for dry air);

δD - refraction lengthening;

σ - ray coordinate;

D - length of the ray trajectory;

L - range to the satellite along direct line.

Basing on the height profile of refraction index of air which is consistent with the standard atmosphere one it was shown (see Fig. 1) that for zenith angles $z > 70^\circ$ both effects considered - refraction lengthening and refraction space struggling - can be quite considerable. However their contributions have different signs and cancel each other in great part when the errors are

added. The residual total error (bias) may range between merely about 1,5 mm for $z=70^\circ$ and merely about 8 mm for $z=80^\circ$.

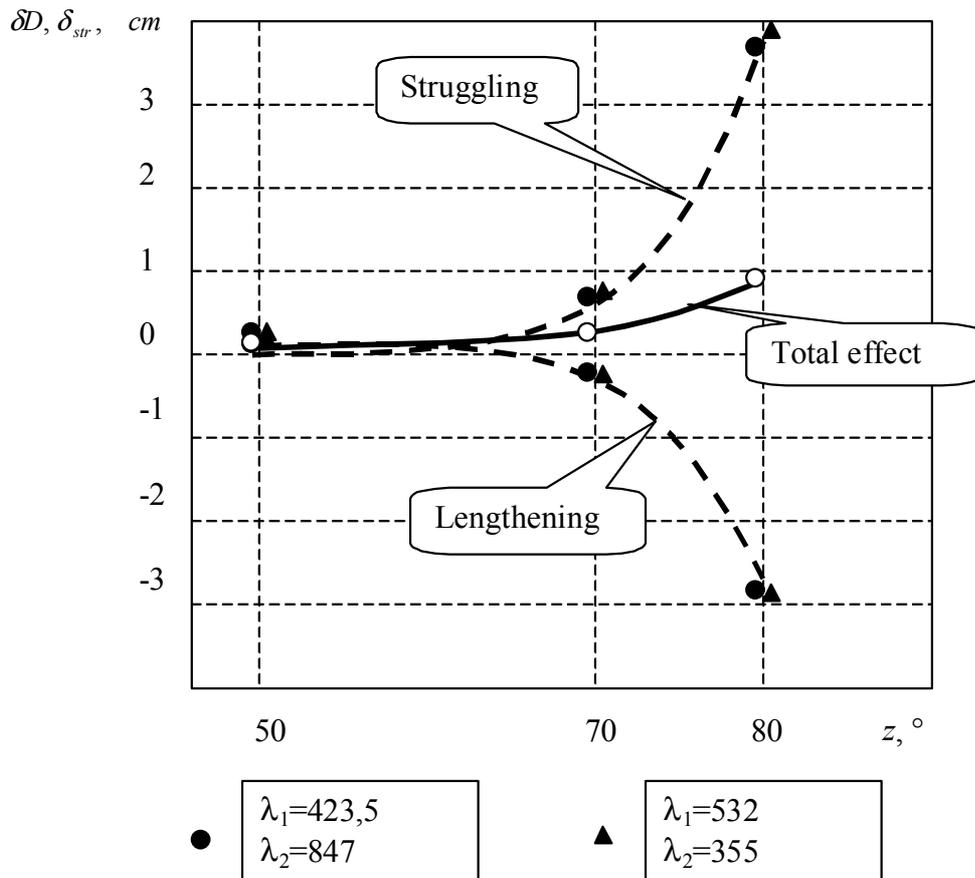


Fig.1. The refraction errors of two-color technique for the standard atmosphere

The same calculation were executed for annual sets of height meteosounding profiles obtained in the five points of Ukrainian territory. The data processing gives the results agree closely with ones presented on Fig. 1. In particular, it was shown that errors researched are varying very slightly from point to point of meteostation location. For example, the bias caused by total refraction effect varies for $z=80^\circ$ in range between 8,2 and 8,6 mm, RMS therewith varies only between 0,6 and 0,9 mm.

The results obtained shows that in the case of measurements considered it is meaningless to insert only one correction compensating only one component of total refraction error as it only will reduce the precision of measurements. Only total refraction effect needs to be compensated if it is necessary. It is possible that for such compensation there will be suitable the correcting formula approximating the dependence obtained in our paper for total refraction error. To clear up as far as universal can be this approximation the further researches are necessary.

References

Prokopov A.V. and Remayev Ye.V., 2000. Refraction limitations of precision of two-wave satellite laser ranging.// Ukrainian Journal of Metrology (Ukrainskiy Metrologicheskii Zhurnal), No.2, 2000, pp. 5 - 9 (in Russian).